

Radiation Hazards

J. F. FILBEE, D.M.R.T.* and J. G. KAPLAN, Ph.D.**

DISCUSSION—J. F. Filbee:

Although it has become of greater importance in recent years with increase in radiation exposure from all sources, both radioactive fallout and medical X-rays, there has always been radiation exposure, ever since the inception of life. We can probably attribute at least part of the mutations, which have led to the progressive alteration of life and which have permitted the operation of natural selection, to be due to the results of radiation effect on our forebears. There has throughout history been a constant shower of cosmic rays striking the earth from outer space. These rays are particles which move at tremendous speeds and which have an enormous penetrating power. They can still be detected in mine shafts many hundreds of feet below the surface, but they are very much more intense above the atmosphere. In fact the atmosphere forms an extremely valuable shield against effect by these radiations. The other continuing source of radiation has been radioactivity, both in the rocks of which the earth is composed, particularly granites, and also in elements which are natural constituents of tissue. For example potassium, which is a constituent of red blood cells, is naturally radioactive, due to a radioactive isotope— K^{40} —which accounts for 30 milli-roentgens (mr) of body radiation in a year as compared with 100 mr from cosmic rays. Carbon itself is feebly radioactive, containing a small amount of C^{14} which is constantly replenished by the action of cosmic rays on carbon dioxide in the atmosphere (and which is available as a clock to assist archaeologists in dating biological materials such as fossils).

This discussion on radiation hazards will cover the following main aspects: firstly, the sources of radiation affecting either the general population or individuals in that population; secondly, the types of radiation injuries seen under different circumstances; and finally, the degree of damage and sequelae likely to be produced by different types of radiation exposure. In this present discussion we are dealing with *ionizing radiation*. This includes both electromagnetic waves such as gamma and X-rays, and particulate rays including beta-particles (electrons), alpha-particles (helium nuclei) and other elementary particles. It does not include other types of radiation such as ultra-violet light, "short-wave", and ultra-sound which do not have the power to ionise matter.

First, the sources of radiation—naturally occurring radiation has already been mentioned to some extent. However, this radioactivity is decreasing all the time due to radioactive decay and some millions of years ago was undoubtedly much more intense than it is now. "Background" radiation is much increased in areas where radioactive ores occur, as for example in Kerala, India, famous for its monazite sands which contain thorium. Inhabitants in some villages may get as much as 800 mr a year from that source. Cosmic radiation supplies about 100 mr per year or 2 mr per week for all of us, but this can be increased considerably by moving to a higher altitude, and for example is multiplied by a factor of three in moving from Halifax to Denver which is at a height of 5,280 feet above sea level.

* J. F. Filbee, M.B., B.S., M.R.C.S., L.R.C.P. (Lond.), Assistant Professor of Radiotherapy, Dalhousie University, Halifax, N. S.

** J. G. Kaplan, A.B. (C.C.N.Y.), A.M., Ph.D. (Col.), Associate Professor of Physiology, Dalhousie University, Halifax, N. S.

Artificial sources of radiation include medical X-rays, radioactive equipment (e.g., luminous watches), occupational exposures and weapons' testing fallout. Medical X-rays vary in their incidence across the world, being almost non-existent in underdeveloped countries and most widely used in the Western nations such as Canada and the United States. Almost every Canadian will have had at least one radiograph taken by the age of 30 years. The *per capita* dose from the diagnostic use of X-rays was estimated to be 100 mr per year in New York for 1956 (1), but it may well be higher. It would probably take \$1200 worth of medical X-rays to every man and woman under thirty to exceed the permissible tolerance dose which has been set out for an average member of the community, and this is one tenth of the permissible dose set for radiation workers. \$200 worth in that period would probably be nearer the mark, and at that would be considerably less than half as important as cosmic ray background. Nevertheless, radiologists are keeping careful watch on their patients' radiation dosage and are forever trying to develop techniques which will minimize exposure. (Let us not attempt to justify the use of X-ray machines in shoe stores). The biggest individual hazard may be said to come from radiation therapy because of the very much higher dosage of radiation involved. Exposures so far discussed have been of the order of a few milli-r, whereas in therapeutic radiology doses are hundreds of thousands of roentgens, probably a million times as great as background. Such doses have a considerable potential for local harm to the tissues. Genetically, however, it is unimportant, as firstly, only a very small fraction of the population receives radiation therapy, and secondly, most of the patients who do are either past child-bearing age or unlikely by virtue of their condition to beget children. Such few patients who remain are treated so circumspectly, with low dosage and careful shielding, that the genetically significant dose, averaged over the whole population (and in considering population effects at low dosage this is permissible) becomes vanishingly small.

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Occupational exposure affects only a small fraction of the general population, and provided it is kept within the doses recommended by the International Commission for Radiation Protection will probably not increase the mutation rate in that group by more than a factor of two. Unrecognized occupational exposure has caused much injury to the groups involved. Two examples that come to mind are the New Jersey dial painters and the Schneeberg miners. The dial painters, in 1917 were employed applying luminous paint, which contains radium, to instruments. Not knowing better they would lick the tips of their paint brushes to bring them to a fine point, and in doing so many absorbed enough radium to cause their later deaths from bone sarcoma or leukemia. The Schneeberg mines in Germany have a high concentration of Radon in the atmosphere. Nearly half of the miners over a considerable period of years died of the "mountain sickness"—cancer of the lung, presumably radiation induced. Such happenings are most unlikely today. Luminous watches probably give a dose to the gonads of 1.5 mr per year.

Fallout weapons' testing is the final element in the population dose. It has increased in recent years but recently it has averaged a gonadal dose of 5-10 mr per year, with the thyroid getting somewhat more from iodine¹³¹. The milk drinking population probably received about 50 mr to the thyroid due to I¹³¹ produced in the 1961 Soviet tests. Thus fallout accounts for about five percent of the total skeletal and gonadal dose, and a higher fraction of the dose to the thyroid (2).

What radiation injuries may be produced and what sort of dose levels are needed to produce them? The genetic risk is highest in the minds of the general public. People don't seem to mind too much about the risk of getting cancer from radiation (any more than the risk of lung cancer deters them from smoking cigarettes), but they hate the idea of genetic damage. For example, a middle aged woman refused to have her chest X-rayed because it might hurt her children, notwithstanding that they were grown up and some thousand miles away in another state. It is very hard to arrive at an accurate figure for the dose of radiation which is required to double the natural mutation rate of the population, but animal experiments suggest that it is something like 50r total at or before the reproductive age. The reproductive age is by convention taken as 30 years for man. If this is so, then a total dose of 10r received by that time would cause less than a 20% increase in the mutation rate, particularly as the relation is probably not linear. Some 3r will be due to cosmic radiation and that leaves 7r for fluorescent watches, fall-out and diagnostic X-rays. As far as occupational exposure is concerned, it is considered not unreasonable to permit a small proportion of the community to increase its mutation rate to a larger degree. 50r for a radiation worker before the age of 30, roughly speaking gives 10 years of work at 0.1r per week. This is the accepted upper limit for radiation workers, although most get very much less than that. There is much confusion about genetic damage; for example, nurses looking after radium or isotope patients have been heard to say things like "I want to have children, too". Such a nurse is not likely to receive more than ten mr or so from one patient or a total gonadal dose in her whole training of more than one or two roentgens. Such doses are far short of those required to cause a measurable increase in the mutation rate. It would take more than a thousand roentgens to sterilize a young woman even temporarily, although a few hundred would suffice in a woman approaching the climacteric. This does not absolve the physician from keeping occupational exposures, especially to the gonads, to a minimum. It is becoming usual to use gonad shields in radiological examinations in the pelvic region, and radiography during pregnancy is kept to the minimum consistent with satisfactory medical care, particularly with regard to X-ray pelvimetry. Genetic damage is probably without a threshold dose—even the smallest dose of radiation is thought to be associated with some hazard; but even in quite high doses the

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risk to an individual of having abnormal offspring is minute, only becoming apparent on the population scale.

Somatic hazards on the other hand typically require higher doses. These include leukemia, bone sarcoma and other malignancies. A survey of the obituary columns of the Journal of American Medical Association of the 1920's and 1930's (3, 4) showed radiologists to have ten times the incidence of leukemia of their non-radiologist brethren. This, however, covers a period when protection against radiation was poorly understood and sketchily practised. A more recent survey of a younger group of radiologists shows no excess mortality (5). There has been some question of the risk of X-ray pelvimetry to the foetus. The latest survey confirmed that the incidence of leukemia in children between 5 and 8 years is doubled by pelvimetry (3). Stewart et al. (6) have recently shown that diagnostic X-rays of the trunk in adults is associated with an increased risk of leukemia. The known risk of leukemia from radiation therapy for ankylosing spondylitis (7) must be measured against the benefit the patient may expect from treatment. It will not deter most radiotherapists from treating such cases. Likewise skin cancers, thyroid tumours and bone sarcomas appear to follow only on high dosage radiation. Although in the absence of any specific evidence for or against their figures, some biologists have suggested that the number of bone tumours in the world population may be increased by as much as 2,000 cases in a generation due to Sr^{90} in fallout presently in existence. This apparently large incidence might approximate to one case per 30 million, say six cases on this continent per year. In the 18 to 20 years since its first use in the diagnosis and treatment of thyroid disorders there has been a remarkable paucity of reports of tumours attributable to radioiodine I^{131} . The great difficulty in assessing all these possible injuries lies in what Eisenbud calls the *noise level*—in other words the additional cases are too few to be observed.

—It is generally agreed that there is an upper limit of radiation dose which can be considered as acceptable for the general population of the world. The differences of opinion therefore lie in the definition of that upper limit. It seems, however, that so long as the additional burden due to fallout is but a small fraction of the natural exposure to cosmic and other unalterable radiation, any injury which it may cause is likely to be of such infrequent occurrence as to be undetectable, and is comparable to the risk of wearing a luminous wrist watch. The possible benefit to the population which will accrue as a result of the knowledge gained in the competition between nations for nuclear war-power should be contrasted with the putative injuries. It is submitted that at present the benefits outweigh the costs, if only the medical uses of radio-isotopes are counted on the credit side.

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COMMENT —J. G. Kaplan:

There are relatively few points in Dr. Filbee's interesting paper with which I disagree but I shall focus this brief discussion on some of these.

Filbee estimates that watches with radioactive dials contribute about 1.5mr/year to the gonads, a figure with which most authorities would agree (1). In his final paragraph, Filbee concludes that the hazard (to mankind) from fallout "is comparable to the risk of wearing a luminous wrist-watch". This comparison is fallacious. The 1.5 mr annual dose rate applies only to those individuals who *wear* luminous watches; furthermore, the genetic effects will of course be produced only when such a watch is worn in the period between childhood and conception of one's last child. To what fraction of humanity does this apply? I know of no data on this subject, but I suggest that one per cent would not be too low an estimate of the world's gonads which are irradiated by luminous watches, during or before the reproductive period. The genetically effective dose to mankind as a whole from this source is thus corrected to 0.015 mr/year, which is about 0.2% of the mean dose which Filbee estimates the gonads of mankind receive from fallout (5-10mr/year). The genetic risk to *mankind* as a whole is thus 500 times as great from fallout as it is from luminous watches.

I have raised this issue because central to it is a crucial and subtle point: the necessity of distinguishing between risks *to an individual* and *to the human race as a whole*.

Parenthetically, let me add that I should like some day to see a discussion of the responsibility of the medical profession *to the human race*, and whether this responsibility may not in some cases conflict with that to individual patients. As areas of possible conflict, let me cite—a) the widespread use of antibiotics in cases where their use is of doubtful benefit (e.g., virus infections), (the conflict stemming from the inevitable selection of resistant bacterial strains resulting from such treatment); b) the better known problems associated with the introduction of modern medical and public health measures in underdeveloped countries, leading to increased population pressure and permanent conditions of grinding poverty and starvation, in the absence of modern technology, agriculture and effective birth control techniques.

Filbee states that "fallout accounts for about 5 per cent of the total skeletal and gonadal dose, and a higher fraction of the dose to the thyroid". I have pointed out elsewhere (2) that many people have incorrectly concluded (as Filbee has not) that since fallout delivers only 5 per cent as much radiation, therefore it only represents one-twentieth of the hazard posed by these other sources. The hazard to man from radioactive fallout stems largely from the incorporation and concentration of specific radioactive elements into physiologically active cells and tissues, such as the concentration of Strontium⁹⁰ into hot spots in the spongy bone, adjacent to the blood-forming cells of the bone marrow (see discussion of this point in references 2 and 3). For example, owing to the tendency of the thyroid to concentrate iodine, the glands of American children received a dose from fallout in 1957-'58 of 100-200 per cent that received from all other sources (4).

Filbee concludes his paper with the following sentences: "The possible benefit to the population which will accrue as a result of the knowledge gained in competition between nations for nuclear warpower should be contrasted with the putative injuries. It is submitted that at present the benefits outweigh the costs, if only the medical uses of radioisotopes are counted on the credit side". I am astonished by this statement for a number of reasons.

In the first place, I fail to see why medical and scientific uses of radioisotopes should be placed to the credit of the race to produce and explode bigger and better nuclear weapons. The medical and biological uses of isotopes had been made clear long before the production of nuclear bombs (de Hevesy, Schoenheimer) and there is no reason whatever why radioisotopes cannot continue to be produced in the absence of the construction and testing of nuclear weapons, as in fact they are in Canada and elsewhere. Was the Second World War a good thing for mankind because it led to the production and wide-spread use of penicillin? Can we not have scientific progress without mass murder?

In the second place, it is amazing that Filbee, who is willing to assign the medical use of radioisotopes to the credit of the nuclear arms race, is apparently unwilling to include the possibility of a nuclear war among its liabilities. The "putative injuries" caused by radioactive fallout are but a minor fraction of the hazard to mankind of the mad nuclear arms race.

In judging whether a particular risk is acceptable, I think one should take note of what I have called the *principle of gratuity*. This principle asserts that no hazard to mankind however small is acceptable if it is gratuitous, that is, if it does not confer a greater compensatory benefit to mankind. I submit that the hazard to mankind from fallout is unacceptable since mankind as a whole receives no compensatory benefit from the explosion of nuclear bombs.

Elsewhere, I have published estimates of the magnitude of the fallout hazard and have concluded that this is "small but real" (3). Nevertheless, I have repeatedly stressed that "the principal argument against the resumption of nuclear tests is not that their biological consequences will be intolerable to mankind, but rather that they will contribute to make a nuclear war more likely" (3, 5).

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In summary: 1) Radioactive fallout is a unique and very democratic hazard, in that it affects all mankind. 2) Some millions of humanity, present and future, will probably have their lives aborted or shortened as a result of the genetic and somatic effects of fallout. This number, while absolutely large, is so small relative to the numbers who will die of these conditions anyway (noise) that it will not be detectable with certainty. 3) A risk which is perfectly acceptable to an individual may not be acceptable to humanity as a whole. 4) The principle of gravity asserts that no risk to humanity, however small it may be is acceptable unless it confers upon mankind some over-riding compensatory benefit. Radioactive fallout from test explosions of nuclear weapons is a gratuitous insult to the health and genetic future of man, conferring no reciprocal benefit. The resultant hazard is thus unacceptable; this is, in fact, the view of virtually every nation in the world, except the major nuclear powers. 5) The major hazard of nuclear tests to mankind lies in their contribution to the spiralling arms race and consequent increase in tension, which in turn might cause the nuclear war which all mankind dreads but seems almost unwilling to avoid.

I am grateful to John Filbee for having invited me to comment on his paper.

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REJOINDER—J. F. Filbee:

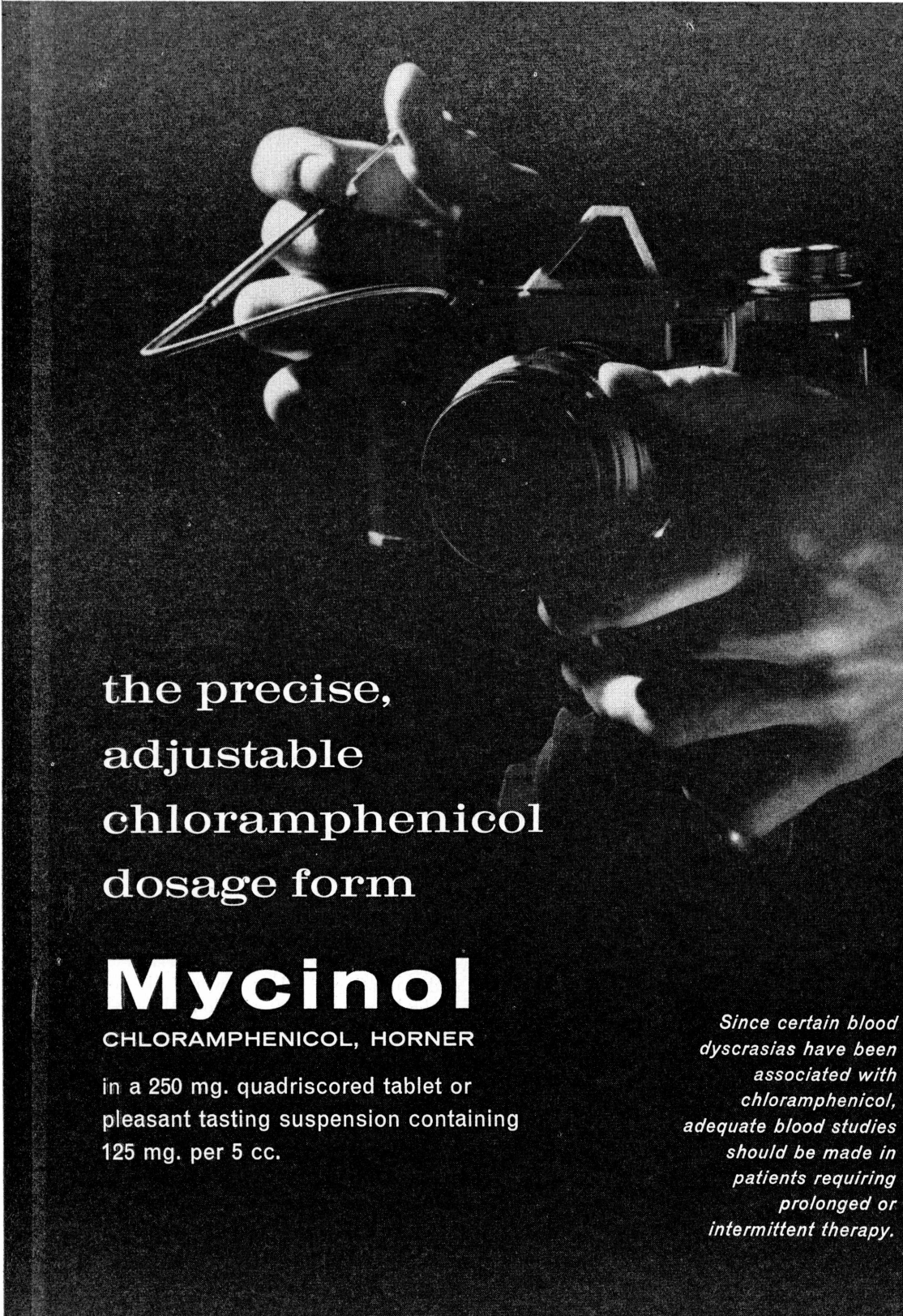
I am indebted to Dr. J. G. Kaplan for his comments, and am not surprised to see that we are in general agreement. I was ill-cast as a Pangloss, and am far from saying that nuclear weapons' testing is "for the best in the best of all possible worlds". Nor would I deny Kaplan's principle 'of gratuity' as an axiom on which a thinking man could base his philosophy and actions.

Unfortunately, as Kaplan would be the first to agree, it is not possible to single out any one advance from the whole stream of scientific discovery, and while regretting the folly of nations we must needs be grateful for any compensating benefits from a cataclysm such as the Second World War. Let us pray that the nuclear arms race does indeed not lead to a nuclear war, but instead may provide the knowledge and technology to permit the development of thermonuclear power, which will very soon be essential as a means of once again allowing mankind to escape from what must be considered ecologically as his Climax—viz. "increasing population pressure and permanent conditions of grinding poverty and starvation". (I, too, would like to see some day a discussion of the responsibility to the human race of, not alone the medical profession, but the whole of biological science, for the present population explosion and its attendant ills.) But I stray from the point. A recent author (1) sums up the present position in a fair manner: "On the basis of the most pessimistic assumptions (no threshold, etc.) the present level of Sr⁹⁰ might increase the incidence of leukemia and bone tumours in Canada by 2-10 cases a year. This is neither negligible nor alarming."

I do not believe that in the absence of the stimulus to research given by the search for nuclear weapons we should have today the use of radio-isotopes on any but the most minute scale, although I agree that the search for bigger and worse bombs has not yet brought any great advantages for mankind.

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